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MEMORANDUM REPORT ARBRL-MR-02804

INITIAL FIRING TEST RESULTS OF THE 35MM SCALED MODEL OF THE 105MM M68 TANK GUN

George Samos
Bertram B. Grollman
Jimmy Q. Schmidt

January 1978

USA ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
USA BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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Experimental Pressure and Velocity Data

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The initial firing test results of the 35mm scaled model of the 105mm M68 tank gun are presented and compared with the calculated performance for three different web propellants. The data include the muzzle velocities and chamber pressures for charge weights varying from 50% to 100% of the charge weight required for the scaled model of the M392A2 APDS round.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION

On the basis of a theoretical study into replica modeling theory,[1] a 35mm gun, which represents a scaled 105mm, M68 tank gun, was designed and fabricated. The purpose of the theoretical study was to investigate the basic dynamics, compressible fluid mechanics and solid mechanics to establish replica modeling behavior. The theoretical study showed that similarity exists for replica models in the transitional ballistics region for sabots provided that the effects of gas viscosity are insignificant and that the Mach number, the materials, the gas status and the ambient conditions are preserved. It was also verified that rate effects in materials upset similarity but that elastic and elastic-plastic material behavior are amenable to similarity under linear geometric scaling provided surface tractions are preserved and acceleration effects are scaled. An examination of the first-order interior ballistic equations also showed similarity for linear geometric scaling. If agreement is found between the firing test data and the modeling theory, then results of other phases of this program may be scaled with confidence.

This report presents results from the first phase of the experimental study, interior ballistics.

II. DISCUSSION

The weapon was set up, instrumented, and test-fired to establish charges and to evaluate three propellant lots obtained from Radford Army Ammunition Plant.

The gun, manufactured by Watervliet Arsenal, is shown in Figure 1. Two BRL Minihat Gages were installed diametrically opposite each other 0.104 metre from the rear face of the tube. A third Minihat Gage was installed in the base of the stub cartridge case, shown in Figure 2. The stub cases were cut down from standard 40mm M25 cases. M1B1A1 percussion primers were used to ignite the M30 propellant. A liner of titanium dioxide/wax additive, shown in Figure 3, was used to mimic the wear-reducing additive used in the M392A2 round, as well as to contain the propellant which did not totally fit in the stub case. The upper part of the lid on top of the liner was slit into flaps which were folded over to enclose the propellant.

The seven perforation 0.0456-inch web M30 propellant for the 105mm gun was selected for the modeling study. The propellant grain has a length (L) of 0.627 inch, a diameter (D) of 0.261 inch and perforation diameter (d) of 0.0261 inch. Its L/D is 2.4 and its D/d is 10. Maintaining this L/D and D/d, a one-third diameter scaled lot of propellant was ordered from Radford. Two additional lots with webs of ±0.020 inch

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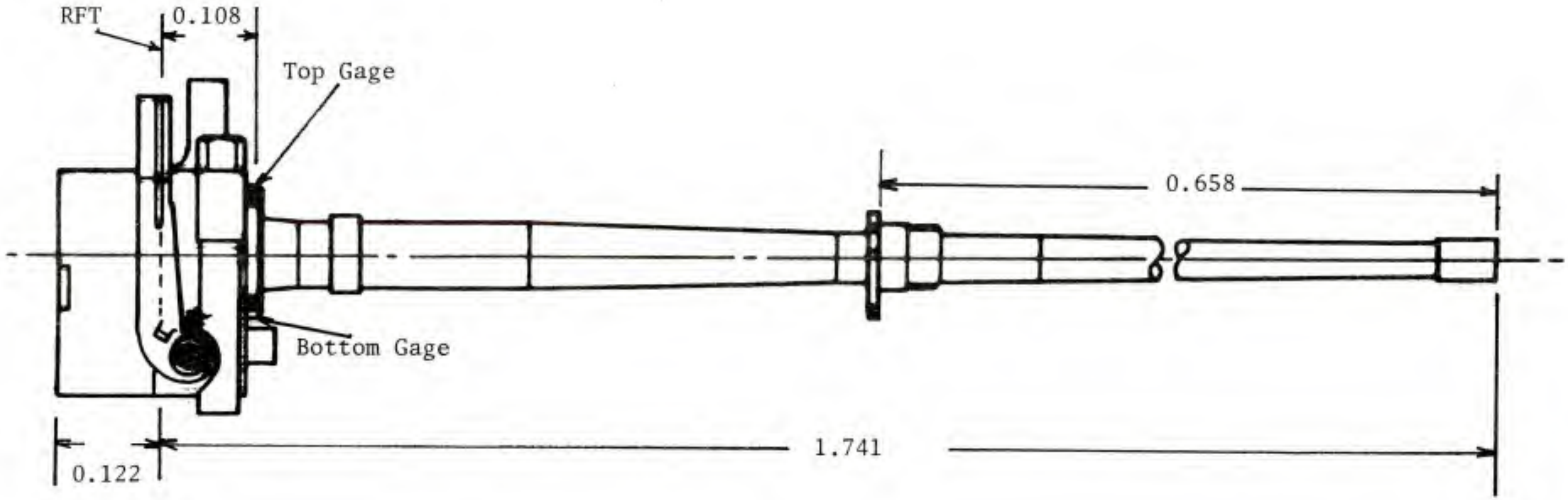
[1] *Dr. B. Burns, R. Deas, unpublished report.*



(Dimensions are in metres)

Figure 1. 35mm Gun

Figure 2. Base Gage Installation

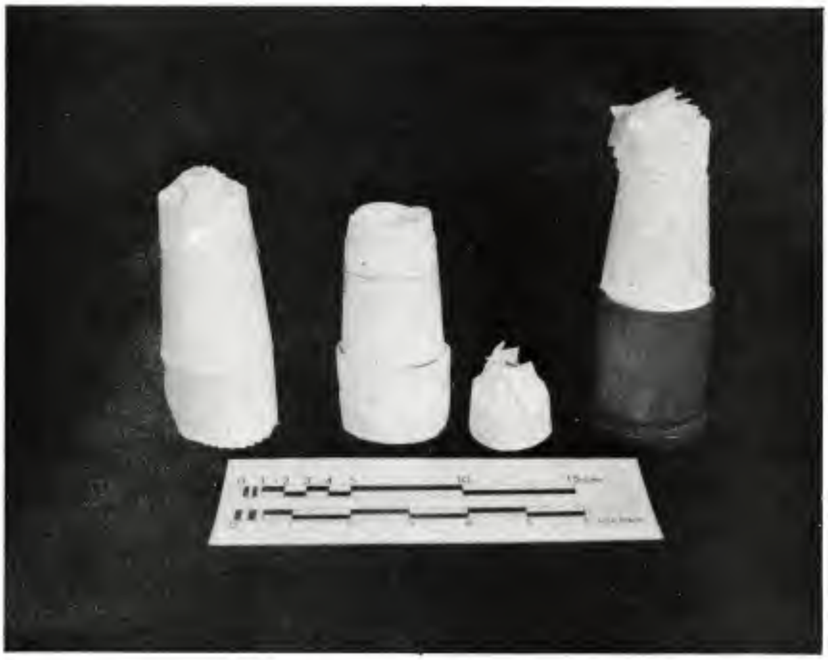


Figure 3. Wear-Reducing Additive

were also ordered. Table I presents the dimensional characteristics of the standard propellant as well as those specified for the scaled propellant when ordered. Propellant Description Sheets are included in Appendix A.

TABLE I. Dimensions of Propellant Grains as Ordered

	W Web in.	L Length in.	D Diameter in.	d Diameter of Perforations in.	
1.	.0456	.627	.261	.0261	(Standard)
2.	.0132	.182	.076	.0076	
3.	.0152	.209	.087	.0087	
4.	.0172	.236	.098	.0098	

Table II presents the dimensional characteristics of the scaled propellant actually received from Radford. These should be compared with items 2, 3 and 4 of Table I.

TABLE II. Dimensions of Propellant Grains as Received

Lot #	$W_{Av.}$ in.	W_i in.	W_o in.	L in.	D in.	d in.	L/D	D/d
E29	.0128	.0073	.0183	.1798	.0810	.0105	2.22	7.7
E30	.0147	.0096	.0198	.2065	.0943	.0123	2.19	7.6
E31	.0156	.0091	.0220	.2321	.1048	.0147	2.21	7.1

W_i = inner web

W_o = outer web

III. EXPERIMENTAL

The firing test program was conducted with 0.46 pound (209 g) slug projectiles shown in Figure 4. Pressure gage outputs and timing signals were recorded on a Honeywell magnetic tape recorder. A 35 GHz interferometer was used to measure projectile displacement and velocity in the tube. Its output was also recorded on tape. Lumiline screens placed known distances downrange were used to obtain muzzle velocity for the higher charge firings by extrapolating the data back to the muzzle. Velocities for all of the rounds were obtained from the interferometer discriminator. Table III presents the pressure and velocity data obtained.

TABLE III. Experimental Results

Round #	Weight of Propellant (g) Lot E29	Lot E30	Lot E31	Pressure MPa P_c	P_t	P_b	Muzzle Velocity, m/s Disc.	Screen
1			100	86	97	89	777	
2			125	128	142	139	934	
3			150	171	197	190	1078	
4			175	228	257	268	1161	
5			200	321	364	357	1314	
6		100		86	111	108	781	
7		125		120	151	150	914	
8		150		190	225	220	1098	
9		175		232	281	272	NG	
10		190		265	317	317	1319	
11	100			97	108	97	788	
12	125			129	154	148	905	
13	150			201	216	212	1048	
14	175			270	306	274	NG	
15	190			332	349	338	NG	
16	195			360	378	370	1314	
17	200			374	390	386	1424	
18	200			372	385	387	1384	
19	200			331	364	357	1338	
20	200			370	394	386	1399	1379
21	205			356	430	406	1302	1443
22	203			336	378	373	1350	1400
23	203			NG	404	395	1133	1423
24	203			402	364	383	NG	1390
25	203			399	384	385	1397	NG
26		205		386	374	379	NG	1439
27		205		398	382	388	NG	1426
28		205		394	396	397	1400	1431
29			205	373	372	401	1390	1375
30			205	391	368	376	1358	1389
31			205	363	359	365	1397	1387

P_c = Cartridge Case Gage

P_t = Top Chamber Gage

P_b = Bottom Chamber Gage

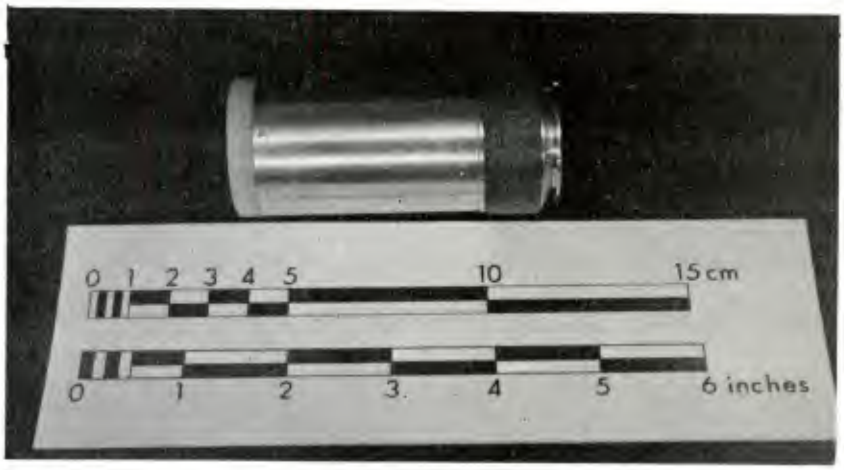


Figure 4. Slug Projectile

The three propellant lots, at the various charge levels, acted as if the webs were larger than they actually were. For the full charge (205 g), Lot E29 with the smallest web had measured pressure and velocity close to that calculated for Lot E30. Table IV presents the calculated pressures and velocities expected from the three propellant lots as ordered.

TABLE IV. Calculated Ballistic Performance for Ordered Propellant

Lot	Pressure MPa	Velocity m/s
E29	498	1543
E30	403	1478
E31	332	1408

Table V presents the pressures and velocities calculated from the propellant data sheets for the three lots as received.

TABLE V. Calculated Ballistic Performance for Received Propellant

Lot	Pressure MPa	Velocity m/s
E29	552	1527
E30	442	1467
E31	400	1416

Table VI presents average pressures and velocities obtained from the three lots during the firing test.

TABLE VI. Experimental Ballistic Performance

Lot	Pressure	Velocity
	MPa	m/s
E29	418	1443
E30	386	1431
E31	365	1384

Figure 5 presents the pressure vs. time curves of the three pressure gages and Figure 6 presents the displacement and velocity vs. time curves from the interferometer data in Table VII for round 22. Similar data for the other rounds are available and can be reduced and plotted if needed.

IV. SUMMARY

Various charge weights of the three lots of scaled propellant have been fired and a charge established for continuation of this program, using scaled M392A2 projectiles. The best charge of the available propellants, for the M392A2, is 205 grams of Lot E30. Charge can now be calculated for other projectiles scaled for the 35mm gun.

Muzzle velocities reported are not considered accurate because of the poor ballistic shape of the slugs which were fired, necessitating as much as 91 metres/second extrapolation back to the muzzle. In the next experiment, utilizing scaled M392A2 projectiles, the rounds will be fired through the spark range, thereby allowing more accurate muzzle velocities to be obtained. Slight discrepencies noted between the calculated and measured values of pressure might be due to dynamic effects of rotating band and bore resistance in scaling. These will be investigated in later phases of this program.

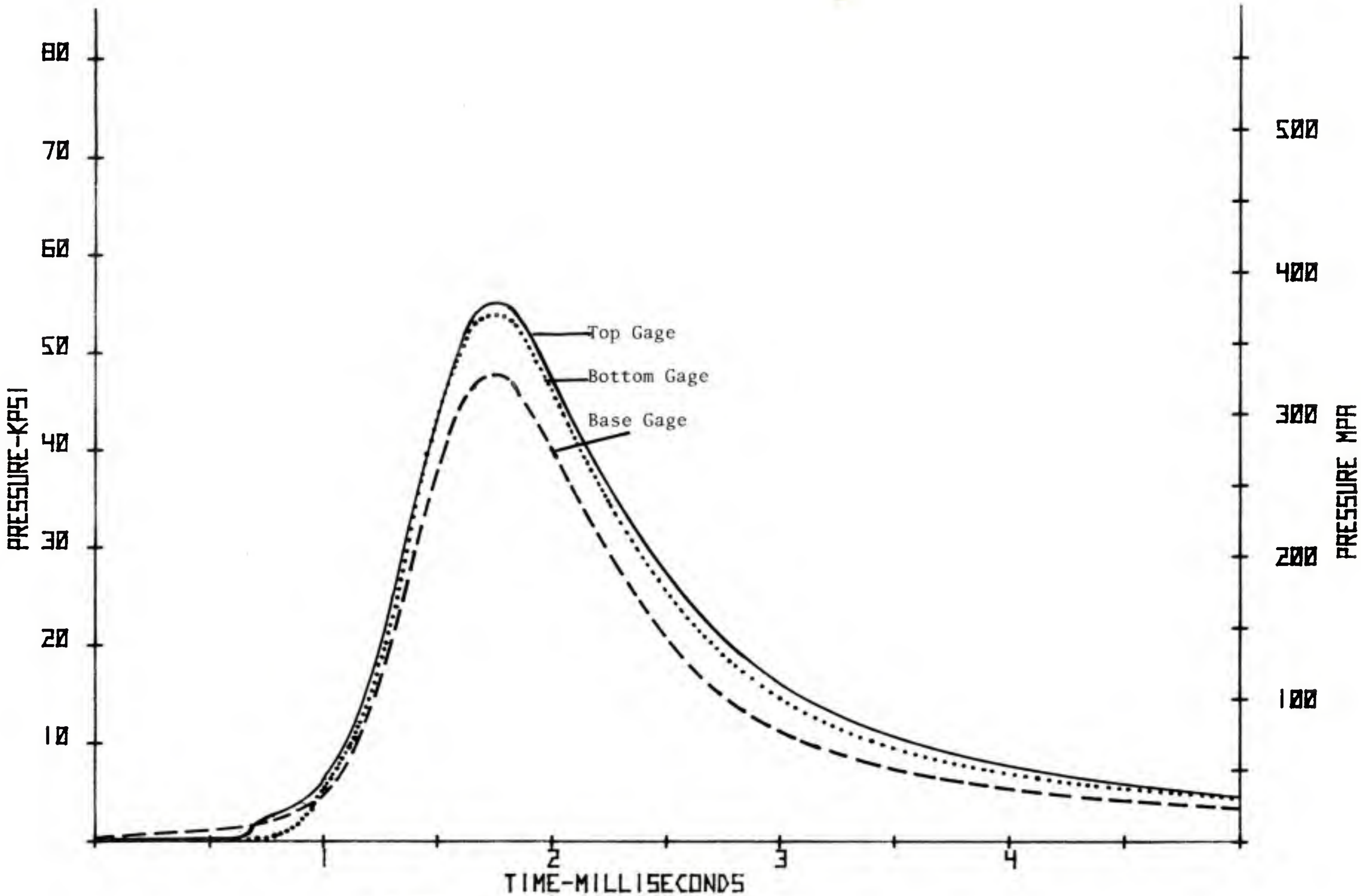


Figure 5. Pressure vs. Time Curves

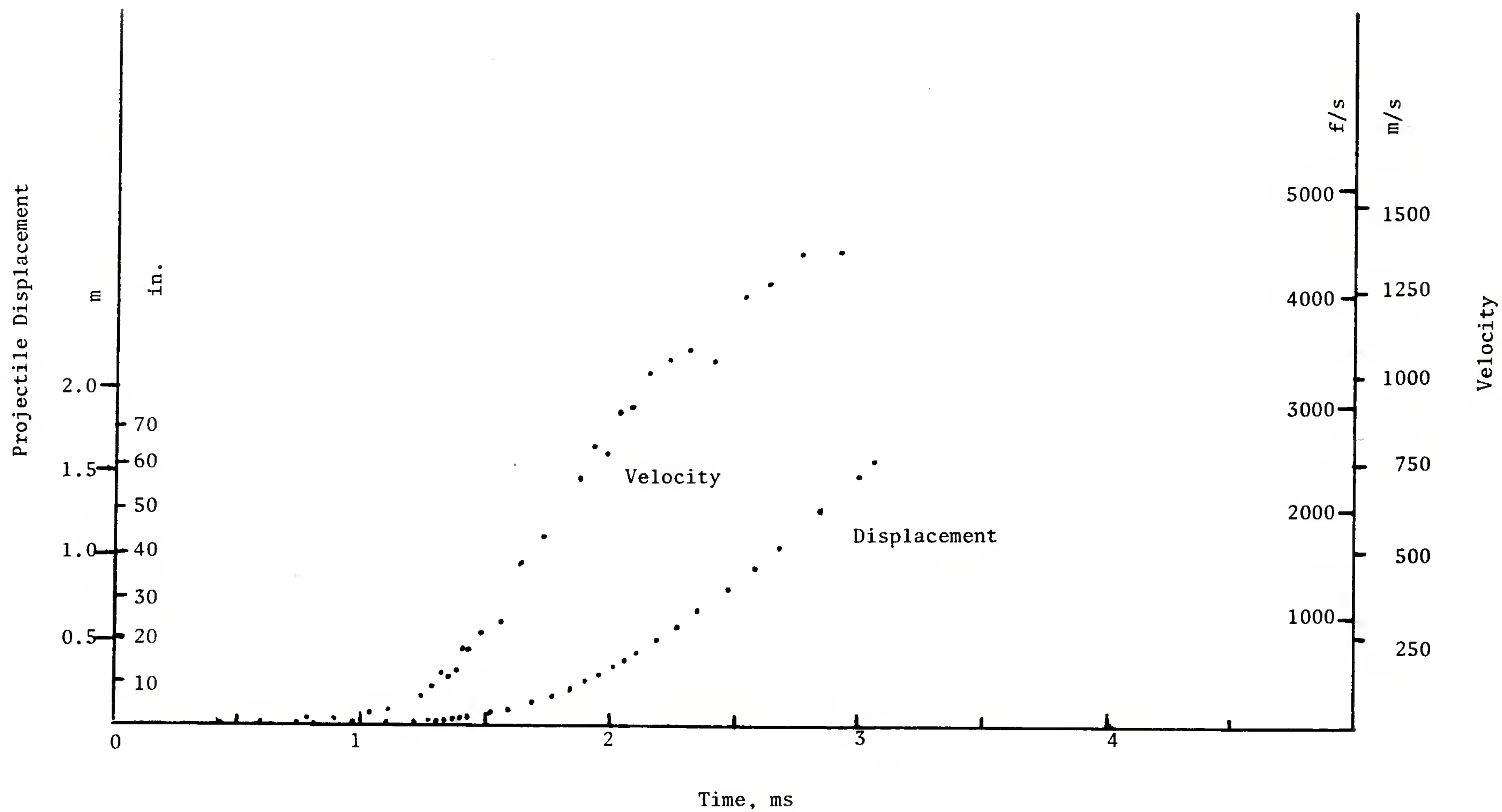


Figure 6. Displacement and Velocity vs. Time Curves

TABLE VII. Interferometer Data

Cycle #	Displacement in.	Displacement m	time ms	Velocity f/s	Velocity m/s	time * ms
0	0	0	0.400	--	--	--
1/4	0.043	.0011	0.700	12	4	0.550
1/2	0.085	.0022	0.78	44	13	0.740
1	0.17	.0043	0.925	49	15	0.853
2	0.34	.0086	1.065	101	31	0.995
3	0.51	.0130	1.175	129	39	1.070
4	0.64	.0163	1.230	258	79	1.202
5	0.85	.0216	1.270	354	108	1.250
6	1.02	.0259	1.300	472	144	1.285
7	1.19	.0302	1.332	442	135	1.316
8	1.36	.0345	1.360	506	154	1.346
9	1.53	.0389	1.380	708	216	1.370
10	1.70	.0432	1.400	708	216	1.390
15	2.55	.0648	1.482	863	263	1.441
20	3.40	.0864	1.555	970	296	1.519
30	5.10	.1295	1.648	1523	464	1.602
40	6.80	.1727	1.728	1770	539	1.688
50	8.50	.2158	1.800	1968	600	1.764
60	10.2	.2591	1.861	2322	708	1.831
70	11.9	.3022	1.915	2623	799	1.888
80	13.6	.3454	1.970	2576	785	1.943
90	15.3	.3886	2.018	2951	899	1.994
100	17.0	.4318	2.065	3014	919	2.042
120	20.4	.5181	2.150	3333	1016	2.108
140	23.8	.6045	2.232	3455	1053	2.191
160	27.2	.6908	2.312	3592	1095	2.272
190	32.3	.8204	2.435	3455	1053	2.374
220	37.4	.9499	2.540	4047	1233	2.493
250	42.5	1.0794	2.642	4166	1270	2.591
300	51.0	1.2953	2.801	4454	1358	2.722
350	59.5	1.5112	2.959	4483	1366	2.880
370	62.9	1.5976	3.022	4497	1371	2.990

$$\text{Velocity} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$\text{time} = \frac{t_2 + t_1}{2}$$

* Time for velocity is midpoint between cycles.

PROPELLANT DESCRIPTION SHEET

Army Lot No. RAD-E-29 of 19 73 Composition No. M30, MP f/105mm M68, 35mm Scaled

Manufactured at RADFORD ARMY AMMUNITION PLANT, RADFORD, VA. Packed Amount 272 Pounds
Contract No. DAAA09-71-C-0329 Date 6-30-71 Specification No. COR Letter SMURO-IE dated 2 March 1973

NITROCELLULOSE

Accepted Blend Numbers	Nitrogen Content	KI Starch (65.5°C)	Stability (134.5°C)
A-35,332	Maximum ___ %	___ Mins	___ Mins
	Minimum ___ %	___ Mins	___ Mins
	Average 12.54 %	45+ Mins	30+ Mins
			Explosion ___ Mins

MANUFACTURE OF PROPELLANT

22 Pounds Solvent per Pound NC/Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds Acetone per 100 Pounds Solvent.
Percentage Remix to Whole 10

PROCESS-SOLVENT RECOVERY AND DRYING

Temperatures °F From	To	Process	Time Days	Hours
		Load Forced Air Dry at Ambient Temperature		
Ambient	140	Increase Temperature 5°F Per Hour		
140	140	Hold at Temperature		24

TESTS OF FINISHED PROPELLANT

Propellant Composition

Constituent	Percent Formula *	Percent Tolerance *	Percent Measured
Nitrocellulose	28.00	±1.30	29.17
Nitroglycerin	22.50	±1.00	21.60
Nitroguanidine	47.70	±1.00	47.42
Ethyl Centralite	1.50	±0.10	1.53
Cryolite	0.30	±0.10	0.28
TOTAL			100.00
Total Volatiles	0.50	Max.	0.21
Graphite Glaze	0.2	Max.	0.09

Stability and Physical Tests

	Formula *	Actual
Heat Test, SP, 120°C	No CC 40'	60'
No Fumes		60'
Form of Propellant		Cyld.
No. of Perforations		7

CLOSED BOMB

	Lot Number	Temp °F	Relative Quickness	Relative Force
Test				
Standard			100.00%	100.00%
Remarks				

PROPELLANT DIMENSIONS (inches)

	Specification	Die	Finished	Mean Variation in % of Mean Dimensions Spec. *	Actual
Length (L)		0.1810	0.1798	6.25Max.	1.38
Diameter (D)		0.0870	0.0810	6.25Max.	4.09
Perf Dia. (d)		0.0140	0.0105		
Web Inner		0.0160	0.0073		
Web Outer		0.0065	0.0183		
Web Avg.		0.0112	0.0128		
Nom. Avg. Web 0.0132					
Web Difference/Std. Dev. in % of Web Average	15 Max.*		86		
L/D	2.10 to 2.50*		2.22		
D/d	5.0 to 15*		7.7		

Dates

Packed	10/5/73
Sampled	10/5/73
Test Finished	10/17/73
Offered	10/18/73
Description Sheets Forwarded	10/25/73

Type of Packing Container Fiber Drums per MIL-STD-652B.
Remarks *Limits from MIL-STD-652B w/EO PA-56070-2 and EO PA-57189-2 shown for information only. Propellant produced on a best effort basis in accordance with referenced COR letter.

Contractor's Representative H. E. BISHOP H. E. Bishop 10-19-73 Government Quality Assurance Representative JAMES E. BLAND

PROPELLANT DESCRIPTION SHEET

U   my Lot No. RAD-E-30 of 19 73 Composition No. M30, MP f/105mm M68, 35mm Scaled

Manufactured at RADFORD ARMY AMMUNITION PLANT, RADFORD, VA. Packed Amount 269 Pounds
Contract No. DAAA09-71-C-0329 Date 6-30-71 Specification No. COR Letter SMURO-IE dated 2 March 1973

NITROCELLULOSE

Accepted Blend Numbers	Nitrogen Content	KI Starch (65.5°C)	Stability (134.5°C)
A-35,332	Maximum ___ %	___ Mins	___ Mins
	Minimum ___ %	___ Mins	___ Mins
	Average 12.54 %	45+ Mins	30+ Mins
			Explosion ___ Mins

MANUFACTURE OF PROPELLANT

0.22 Pounds Solvent per Pound NC/Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds Acetone per 100 Pounds Solvent

Percentage Remix to Whole 10

Temperatures °F From	To	PROCESS-SOLVENT RECOVERY AND DRYING	Time Days	Hours
		Load Forced Air Dry at Ambient Temperature		
Ambient	140	Increase Temperature 5°F Per Hour		
140	140	Hold at Temperature		24

TESTS OF FINISHED PROPELLANT

Propellant Composition Constituent	Percent Formula *	Percent Tolerance *	Percent Measured	Stability and Physical Tests	Formula *	Actual
Nitrocellulose	28.00	±1.30	28.48	Heat Test, SP, 120°C	No CC 40'	60'
Nitroglycerin	22.50	±1.00	22.81	No Fumes		60'
Nitroguanidine	47.70	±1.00	46.90	Form of Propellant		Cyld.
Ethyl Centralite	1.50	±0.10	1.53	No. of Perforations		7
Cryolite	0.30	±0.10	0.28			
TOTAL			100.00			
Total Volatiles	0.50	Max.	0.27			
Graphite Glaze	0.2	Max.	0.08			

CLOSED BOMB

	Lot Number	Temp °F	Relative Quickness	Relative Force
Test				
Standard			100.00%	100.00%
Remarks				

PROPELLANT DIMENSIONS (inches)

	Specification	Die	Finished	Mean Variation in % of Mean Dimensions Spec*	Actual
Length (L)		0.2070	0.2065	6.25Max.	1.74
Diameter (D)		0.0990	0.0943	6.25Max.	2.60
Perf Dia. (d)		0.0160	0.0123		
Web Inner		0.0205	0.0096		
Web Outer		0.0085	0.0198		
Web Avg.		0.0142	0.0147		
Nom. Avg. Web 0.0152					
Web Difference/Std. Dev. in % of Web Average	15 Max.*		70		
L/D	2.10 to 2.50*		2.19		
D/d	5.0 to 15*		7.6		

DATES

Packed 10/5/73
Sampled 10/5/73
Test Finished 10/17/73
Offered 10/18/73
Description Sheets Forwarded 10/25/73

Type of Packing Container Fiber Drums per MIL-STD-652B.

Remarks
imits from MIL-STD-652B w/EO PA-56070-2 and EO PA-57189-2 shown for information only. Propellant produced on a best effort basis in accordance with referenced COR letter.

Contractor's Representative H. E. BISHOP

Government Quality Assurance Representative JAMES [illegible] BLAND

PROPELLANT DESCRIPTION SHEET

U.S. Army Lot No. RAD-E-31 of 19 73 Composition No. M30, MP f/105mm M68, 35mm Scaled

Manufactured at RADFORD ARMY AMMUNITION PLANT, RADFORD, VA. Packed Amount 291 Pounds

Contract No. DAAA09-71-C-0329 Date 6-30-71 Specification No. COR Letter SMURO-IE dated 2 March 1973

NITROCELLULOSE

Accepted Blend Numbers	Nitrogen Content	KI Starch (65.5°C)	Stability (134.5°C)
A-35,332	Maximum ___ %	___ Mins	___ Mins
	Minimum ___ %	___ Mins	___ Mins
	Average 12.54 %	45+ Mins	30+ Mins
			Explosion ___ Mins

MANUFACTURE OF PROPELLANT

0.22 Pounds Solvent per Pound ~~NC~~ Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds Acetone per 100 Pounds Solvent.

Percentage Remix to Whole 10

Temperatures °F From	To	PROCESS-SOLVENT RECOVERY AND DRYING	Time Days	Hours
		Load Forced Air Dry at Ambient Temperature		
Ambient	140	Increase Temperature 5°F Per Hour		
140	140	Hold at Temperature		26

TESTS OF FINISHED PROPELLANT

Propellant Composition: Constituent	Percent Formula *	Percent Tolerance *	Percent Measured	Stability and Physical Tests	Formula *	Actual
Nitrocellulose	28.00	±1.30	28.30	Heat Test, SP, 120°C	No CC 40'	60'
Nitroglycerin	22.50	±1.00	22.55	No Fumes		60'
Nitroguanidine	47.70	±1.00	47.33	Form of Propellant		Cyld.
Ethyl Centralite	1.50	±0.10	1.54	No. of Perforations		7
Cryolite	0.30	±0.10	0.28			
Total			100.00			
Total Volatiles	0.50	Max.	0.28			
Graphite Glaze	0.2	Max.	0.07			

CLOSED BOMB

	Lot Number	Temp °F	Relative Quickness	Relative Force
Test				
Standard			100.00%	100.00%
Remarks				

PROPELLANT DIMENSIONS (inches)

	Specification	Die	Finished	Mean Variation in % of Mean Dimensions: Spec. *	Actual
Length (L)		0.2330	0.2321	6.25 Max.	1.92
Diameter (D)		0.0112	0.1048	6.25 Max.	3.37
Perf. Dia. (d)		0.0180	0.0147		
Web Inner		0.0174	0.0091		
Web Outer		0.0115	0.0220		
Web Avg.		0.0145	0.0156		
Nom. Avg. Web	0.0172				
Web Difference/Std. Dev. in % of Web Average	15 Max. *		82		
L/D	2.10 to 2.50 *		2.21		
D/d	5.0 to 15 *		7.1		

DATES

Packed 10/5/73

Sampled 10/5/73

Test Finished [illegible]

[illegible]

Description Sheets Forwarded 10/31/73

Type of Packing Container: Fiber Drums per MIL-STD-652B.

Remarks: * Limits from MIL-STD-652B w/EO PA-56070-2 and EO PA-57189-2 shown for [illegible]

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